Assessing Navigational Teamwork through Relevance and Situational Correctness of Communication

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Abstract

Efficient communication among team members is an essential prerequisite for successful team performance. Previous studies have observed a relationship between the relevance of communication and team performance. The purpose of the present study was to investigate whether both relevance and correctness of communication is associated with team performance during high-speed coastal navigation. Additionally, as there are few studies that have assessed the time-dependent association between communication and team performance, this study has attempted to demonstrate such association. An experiment involving high-speed navigation in the inner Oslo Fjord was conducted with a three-person team in a maritime desktop simulator. In total 9 teams participated in the study. The team members were required to communicate verbally in order to perform the navigational task. The verbal communication acts that occurred during the navigational experiment were coded with regards to their relevance (relevant/irrelevant) and situational correctness (correct/incorrect). The ratings were merged to form a combined communication score ranging from +1(‘*good*’) to -1 (‘*wrong*’). The measures of relevance, correctness, and the combined communication score were tested for correlation with navigational team performance measured by deviation from planned route. The results revealed that relevant communication (irrespective of its correctness) had no relationship with team performance (r = .01). Ratio of ‘*good*’ communication showed a not significant small to medium positive correlation with team performance (r = -.191), whereas ratio of ‘*wrong*’ communication showed a significant medium to small negative correlation (r = .237). Most interestingly, the association between the combined communication score and team performance demonstrated a significant medium to large positive correlation (r = -.349). Hence, both relevancy and correctness of the communication seems to be associated with increased team performance. Also, the study was able to identify a significant time-dependent association between communication and team performance for three of the nine teams in the experiment.

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Introduction

Accidents at sea are associated with high numbers of causalities and pose a considerable threat to the environment (Gould, Røed, Koefoed, Bridger & Moen, 2006). A number of investigations of accidents occurring in complex sociotechnical systems find that communication and coordination among system components are major contributing factors to industrial accidents (Woods & Branlat, 2011). Communication errors are estimated to be responsible for 40% of marine causalities (The Marcom Project, 1999).

Efficient communication between team members is a crucial factor for acquisition and maintenance of *Situation Awareness* (SA) (*e.g.* Stanton, Salmon, Walker & Jenkins, 2010; Sorensen & Stanton, 2013; Nofi, 2000). SA refers to an individual's awareness of a dynamic external situation (Endsley, 1995a). The phenomenon has a dynamic nature and is tightly interwoven with situational changes in the environment (*e.g.* Smith & Hancock, 1995; Endsley, 2015).

Acquiring adequate levels of SA is considered as a critical commodity for successful performance in teams working in collaborative systems (Shu & Furuta, 2005; Nazir, Colombo & Manca, 2012). Increased levels of SA have shown to be associated with increased level of team performance (*e.g.* Sorensen & Stanton, 2013; Nazir, Sorensen, Øvergård & Manca, 2015; Salas, Burk, Stagl, 2004; Leonard, Graham & Bonacum, 2004). Today, teams are widely used in time-critical and complex environments (Fiore, Salas, Cuevas & Bowers, 2003) and such settings place greater demands on the team's ability to adapt to a dynamic external environment. In the maritime setting, a dynamic understanding of the navigational situation among the bridge team plays a crucial role for safe and efficient operations (John, Brooks, Wand & Schriever, 2013).

Researchers have examined the association between SA and team performance seeking to achieve a comprehensive understanding of the relationship. For instance, Sorensen & Stanton (2013) investigated the connection between the relevance of communication and team performance and found a high positive correlation (r = .923) between situational relevance and team success. Similarly, Salas *et al*. (2004) who evaluated a case study using the air accident investigation report for the crash of American Airlines Flight 965 (20th of December 1995), concluded that collapse in communication and lack of SA were crucial contributing factors in the incident. Clearly, SA has a strong connection to team performance as has been noted by several researchers (*e.g.* Leonard *et al*, 2004; Endsley, 1995a).

Whilst the mentioned research provides important contributions to establishing the relationship between SA and performance, little emphasis have been placed on the matters related to content of the communicated information shared between system components. Moreover, most of the research accounting for content of communication has mainly been focusing on relevance (Svensson & Andersson, 2006). Correctness of communicated information has been discussed by several researchers (Flach, 1995; Stanton *et al.*, 2006; Salmon *et al.*, 2008a), however, there are few studies evaluating the effect of taking into account the correctness of the communication among sociotechnical teams (John *et al*., 2013). The present study is widening the lens by examining both relevance *and* correctness of communication shared between team members.

Additionally, a common issue for the previous studies that have examined the relationship between SA and team performance is that performance has normally been measured as a summary of task completion (*e.g*. at the end of a series of tasks). This approach does not reflect the dynamic properties (Ward, 2002) of SA that emerges through interaction with situational characteristics in the environment and between agents (Endsley, 1995a). This study is making an attempt to evaluate the dynamic association between SA and team performance and how SA these variables are related in time.

Theoretical Approaches to SA

In order to understand how SA impacts team performance in sociotechnical environments, a natural starting point would be to turn to the theoretical literature regarding SA. The most predominant definition of SA is advocated by Endsley (1995a) who defines SA as "*the perception of the elements in the environment within the volume of time and space, the comprehension of their meaning and the projection of their status in the near future*" (p. 36). According to Endsley (1995a), SA is understood as an internal cognitive product that is based on situational assessments. It includes three separate levels: perception, comprehension, and projection (Endsley, 1995a). Following the three level model of SA, an individual is assumed to direct attention towards critical elements in the situation (*perception*), integrate the elements in order to understand their meaning (*comprehension*) and make assumptions about the future states (*prediction*) and respond appropriately.

Several researchers have taken a similar position as Endsley (1995a, 1995b), advocating the psychological school of thought (*e.g.* Smith & Hancock, 1995; Bedny & Meister, 1999), however introducing more dynamic explanations of SA (*e.g*. by accounting for the individuals interaction with the external environment and how this interaction affects their mental models and future actions).

The theoretical development of the SA concept has gradually changed focus from a sole individual approach to an understanding of SA as differentiated among team members

(Salmon, Stanton, Walker & Jenkins, 2009). This development may to some extent be caused by the increased complexity of sociotechnical systems and work procedures within such systems, thus requiring coordination of teams and team members (Fiore *et al*., 2003; Salas, Cooke & Rosen, 2005).

SA in Teamwork

Teamwork is a multifaceted phenomenon involving activities such as interaction, communication and coordination, hence team SA is significantly more complex than individual SA (Salas, Prince, Baker & Schrestha, 1995). A common definition of a team SA claim that it is "*a distinguishable set of two or more people who interact, dynamically, interdependently, and adaptively toward a common and valued goal/objective/mission, who have each been assigned specific roles or functions to perform*" (Salas, Dickinson, Converse & Tannenbaum, 1992, p. 4).

Efficient teamwork requires team members to possess specific knowledge of their own and other team members work tasks and responsibilities, skills relevant for their work tasks, and a positive attitude towards working in a team (Salas, 2005). It is argued that well-functioning teams can perform complex tasks more satisfying compared to individual operators (Orasanu & Fischer, 1997), and this might explain the extensive use of team in sociotechnical settings.

The development of team approaches to SA can be exemplified by Salas *et al*. (1995) who introduce the term team SA which is define as "*the shared understanding of a situation among team members at one point in time*"(p. 131). Moreover, team SA is claimed to be a multi-dimensional concept comprising the individual team members` SA, shared SA related to the other team members, and also SA of the overall team (Salmon *et al*., 2008b).

Additionally, Endsley (1995a) and Endsley & Jones (1997) offer an alternative approach to team SA by differentiating between team SA and shared SA, claiming that the latter refers to the SA requirements of individual team members that they hold in common. More specific, the team members have independent SA requirements for their task, however, some of the requirements might be common with the requirements of other team members. Consequently, shared SA is defined as*" the degree to which team members have the same SA on shared SA requirements*" (Endsley & Jones, 1997, p. 54). Oppositely, team SA is defined as "*the degree to which every team member possess the situation awareness required for his or hers responsibilities*" (Endsley, 1995b). Team members need to perceive, comprehend and predict SA components related to both their individual tasks and those necessary for other team members (Endsley, 1995b).

More recently, the concept of *Distributed Situation Awareness* (DSA), which takes a systems approach to SA, has received significant attention within the SA literature (*e.g*. Artman & Garbis 1998, Stanton *et al*., 2006; Salmon *et al*, 2009; Sorensen & Stanton, 2013). The DSA approach is underpinned by the distributed cognitive theory introduced by Artman and Garbis (1998) which focuses on the overall joint cognitive system when assessing SA in collaborative environments. Echoing Artman and Garbis' (1998) perspective, Stanton *et al.* (2006) laid the foundation for a theory of DSA, which is defined as "*activated knowledge for a specific task, at a specific time within a system*" (p. 51). Hence, DSA can be understood as a dynamic phenomenon, where information contained by the system is activated at different points in time according to the task being performed and its associated goals (Salmon *et al*., 2008a; Sorensen, Stanton & Banks, 2011).

Furthermore, this approach take a systems perspective to SA claiming that SA is not exclusively distributed across agents who make up the team but also artefacts that they use during team performance (Salmon *et al*., 2009). Consequently, the focus is on the interaction among team members and artefacts comprising the system rather on the team members' individual mental processes (Artman & Garbis, 1998). Thus, none of the team member possesses the overall SA, however, it is distributed across the joint cognitive system (Salmon *et al*., 2008a).

The theory of DSA is concerned with how information is applied and distributed among the systems' agents. It is suggested that DSA is developed as a result of coordination among the system's agents and that it is the system that collectively holds the SA necessary for the task performance (Stanton *et al*., 2006). Hence, the *links between the agents* are considered as more important than the agents themselves in maintaining DSA (Stanton, Salmon, Walker & Jenkins, 2009).

Teamwork and Communication. In order to fully understand the concept of DSA it is crucial to comprehend the manner in which teams interact and share information when performing their task. DSA occurs as a consequence of information exchange between the different agents (both human and non-human) of a system, which is achieved through interaction or exchange (Salmon *et al*., 2009). Communication is claimed to function as one form of SA transaction, which allows DSA to develop within a distributed team (Stanton *et al*., 2009). Communication enables teamwork by ensuring that the required information is given to the appropriate agents at the correct time (Sorensen & Stanton, 2013; Salmon *et al*., 2009). Furthermore, communication as a form of SA transaction enables team members to perform their specific task and thus supports effective team performance (Sorensen, 2012). Information exchange between systems' agents (both human and non-human) has been found to be closely associated with high levels of SA (Sasou, Nagasaka & Yukimachi, 1993). Additionally, high levels of SA have been found to be related to high levels of performance in teams (*e.g.* Sorensen & Stanton, 2013; Endsley, 2000; Salas *et al*., 2004; Leonard *et al*., 2004). Communication is therefore identified as key aspect of the development of SA in collaborative settings (Sorensen & Stanton, 2013; Nofi, 2000).

Due to the complex and time-critical environment on board a high-speed vessel, teams are present to a great extent in maritime settings (John *et al*., 2013). Humans operating in sociotechnical systems interpret information differently depending on their goal, roles, and tasks (Stanton *et al*., 2010). Through efficient and successful bridge team communication, DSA can be developed and maintained within the navigational system agents, which in turn can have a positive impact on safe operations of sea-going vessels (John *et al.*, 2013).

Evaluating and Measuring Teamwork

A recent study performed by Sorensen & Stanton (2013) demonstrated that relevant communication is strongly correlated with task success (r = .923) and moderately negatively correlated with poor task success (r = -.52). DSA was assessed by measuring relevant concepts communicated by team members during a simulated strategy game. The relevancy of communication was given by the ratio of relevant statements divided by the total number of statements. The relevance of communication was defined by a Propositional Network (Stanton *et al*., 2006) that contained the relevant concepts involved in the specific scenario. The results of the mentioned study indicate that communication of relevant concepts may be a good indicator of DSA.

As noted by Flach (1995) it is important to identify the relevant concepts. In order to address the issues of meaning (*e.g* "what matters") the correspondence between the operators awareness and the constraints in the environment needs to be considered. Flach (1995) argue "*The question of correspondence (correctness or appropriateness) requires consideration of the relation between the cue (i.e. information) processed and the facts of the world*". Based on Flach's (1995) argumentation, communicated statements need to convey both relevant information and situational correct information related to the conditions in the environment.

In the same vein, Salmon *et al*. (2009) have addressed the issue with quality of shared information, stating that the quality of the SA transactions taking place in a team setting need also be evaluated. Integrating information that seemingly are considered as relevant, but which is in fact incorrect, can lead to agents updating their SA based on erroneous information. This again can disrupt the systems` awareness, which may have unfortunate consequences. Stanton *el al*. (2006) have also addressed the matter regarding correctness of information arguing that a situation requires the use of appropriate knowledge that relates to the state of the system and the changes that occur as a consequence of variations in the situation.

Aim of the Present Study

The main purpose of the present study is to investigate whether relevance *and* correctness of communication during high-speed coastal navigation is associated with navigational team performance. *First*, this study has attempted to replicate Sorensen & Stanton's (2013) findings of the relationship between relevancy of communication and team performance which demonstrated a strong positive correlation between relevance of communication and team performance (r = .923). For this study, it meant that it was expected that teams with a high number of instances of relevant communication demonstrated high team performance (decreased deviation from the planned route measured by cross-track error). Hence, the following hypothesis was tested:

Hypothesis A1: There is a positive correlation between ratio of relevant communication and team performance

Second, this study has made attempts to extend Sorensen & Stanton's (2013) method by including evaluation of the situational correctness of the team members' statements during the experimental task. The extension is based on the assumption that statements that are relevant are not necessarily correct (Flach, 1995). In fact, communication that is relevant and incorrect may appear correct to other team members because relevant terms are applied. Agents might then update their SA based on erroneous information. Additionally, the inclusion of evalution of correctness is also done due to the contextual activity in coastal high-speed navigation whereby incorrect statements may have immediate disastrous consequences (The Marcom Project, 1999).

In the present study, the communicated statements are rated as either relevant/irrelevant and correct/incorrect. Statements that are relevant and correct are categorized as '*good*' whereas statements that are relevant and incorrect are termed '*wrong*'. '*Good*' statements are expected to be positively related to team performance. Teams communicating '*good*' (relevant and correct) statements are expected to reduce the distance to the planned route (increased team performance). Oppositely, '*wrong*' (relevant and incorrect) statements are expected to have a negative association to team performance. Therefore, teams communicating erroneous statements are expected to increase the distance to the planned route (decreased team performance). To investigate these expectations, the following hypotheses were tested:

Hypothesis A2a: There is a positive correlation between ratio of 'good' communication and team performance.

Hypothesis A2b: *There is a negative correlation between the ratio of 'wrong' communication and team performance.*

In order to evaluate the effect of both relevancy and correctness, a combined communication score ranging from 1 ('*good*'= relevant and correct statements) to -1 ('*wrong*'= relevant and incorrect statements) was formed. Furthermore, the relationship between the average of the combined communication scores and team performance was investigated. This was done to explore whether this relationship had a larger magnitude than the correlation between relevant communication and team performance. It was anticipated that the combined communication score would have a positive association with team performance. Accordingly, teams sharing information that is both relevant and situational correct were expected decrease the distance to the planned route (increased team performance). Hence, the following hypothesis was tested for:

Hypothesis A3: There is a positive correlation between the combined communication score and team performance.

Few studies have investigated the dynamic correspondence between of SA and team performance. This study has attempted to investigate the dynamic relationship between SA and navigational team performance by cross-correlation time-series analysis. The time-series of communication was anticipated to have a delayed effect on the time-series of navigational performance. In other worlds, since communication errors do not immediately result in an accident/failure it was expected that the effect of erroneous communication acts would only be apparent after some time and evident in degraded navigational performance. To measure this, the time-lagged correlation of communication measurement and performance are tested for so-called lagged effects (Locascio, 1982). More specifically, communication measurements at time ‘n’ (t_n) are correlated with team performance metrics at increasing time lags (t_{n-1}, t_{n-2}, and so on). This is done to identify at which lag there is a systematic relationship between communication and performance within each team. Ultimately, the analysis can provide knowledge of the co-variation the relevance of communication and team performance. In this sense, it is not possible to identify real causal relationships, however, a rather narrow set of causality – namely predictive causality also called *Granger causality* (Granger, 1969) may be identified. Moreover, cross-lagged correlations in time (*e.g.* changes in time) will give a more suitable support for making causal inferences regarding the relationship between the SA and performance. In order to investigate this notion the following hypothesis was tested:

Hypothesis T1: There is a time-lagged positive cross-correlation between communication and navigational performance.

Method

About the Project

One student from the Master Program in Work and Organizational Psychology at the University of Oslo has been responsible for the present research project and carried out all activities, including preparation of the experimental set-up in a laboratory setting, planning of the navigational scenario for the experiment, and implementation of the experimental task in the simulator. After data collection was finalized, data was transcribed, coded, computed, and analyzed. Technicians provided support regarding complex technical matters related to the simulator. The initial idea for the study was formulated by Professor Kjell Ivar Øvergård at Buskerud and Vestfold University College. Additionally, support related to the data analysis was provided by Kjell Ivar Øvergård, who also assured the quality of the analysis.

Permission to conduct the study was sought and accepted by Social Science Data Service (NSD) prior to the recruitment process. Testing of the experimental scenario and the technical equipment was conducted though several pilot runs before the experiment was carried out.

The work involved in this study has resulted in a conference proceeding that is currently in press (Øvergård, Nielsen, Nazir, Sørensen, 2015). The author of the present research (Nielsen) has contributed with data collection, transcription of data, participated in data analysis, and written a first draft used as a basis for the conference paper. The first author of the conference paper (Øvergård) had the idea for the conference paper, wrote the final version of the paper, performed data analysis and acts as corresponding author.

Participants

In total, 9 teams each consisting of three persons (22 male, 5 female, see table 1) participated in this study. The participants were second and third year students attending the bachelor program in maritime studies located at the Buskerud and Vestfold University College (HBV). Their age ranged from 20 to 38 years (Mean = 24.22, SD = 4.47). The participants were familiar with practicing in maritime simulators, as simulator training was part of their degree course. The students were used in this study on the grounds of having experience with navigation in simulators. Permission to conduct this study was sought and accepted by the Norwegian Social Science Data Service (NSD) (Appendix A)

Prospective Power Analysis

Following available research (*e.g.* Sorensen & Stanton, 2013) a prospective power analysis was performed with an assumed effect size of .92 Pearson Correlation with an alpha-level of .05 (5 %) and a desired statistical power of .80 (80 %). The results indicated that the study should include at least 12 teams in order to be able to statistically identify the expected effect size.

Table 1.

Distribution of age, experience, and gender within each team.

	Age		Experience		Gender	
	M	SD	M	SD	F	M
Team 1	25.33	7.57	2.17	0.67		3
Team 2	23.00	2.65	1.50	0.00		3
Team 3	21.00	0.00	1.80	0.29		3
Team 4	27.67	8.90	2.00	0.00		3
Team 5	25.33	4.50	1.83	0.29	2	1
Team 6	21.67	0.58	2.83	0.29		3
Team 7	23.67	1.53	2.50	0.00		3
Team 8	23.33	1.53	3.00	1.00	2	1
Team 9	27.00	5.20	2.00	0.87	1	2

Sample

Recruitment. The inclusion criterion for participation in this study was that participants attended the second or third year in the bachelor program in nautical studies at HBV. The students were contacted in breaks between classes, where they were given information regarding the main purpose of the research project and the experimental set-up. The participants were also presented with information regarding what their involvement would entail such as anticipated duration of the experiment and where it would be conducted. The students voluntarily signed themselves up on a registration list. They were allowed to choose appropriate time and which team to attend. In total 27 out of 40 students participated in the study which enabled 9 teams. It was done no randomisation across team or with regards to the participants' experience.

Simulator Set-Up

The experiments were conducted using a desktop version of the Kongsberg Polaris bridge simulator (Kongsberg Maritime, n.d.). The simulator was equipped with a visual system (120 degrees forward view) that enabled realistic and detailed re-creations of vessel movement, environments, weather, and sea conditions (Kongsberg Maritime, n.d.). The simulator contained the following information: 1) Conning which provided information regarding speed, course, and rudder angle. 2) RADAR (Radio Detection and Ranging) – utilized as an object-detection system that provided the navigation team with information regarding altitude, range, direction, movement of other vessels as well as shoreline. Accordingly, the simulator was equipped with tools and instruments available at ships bridges, which was sufficient to perform the navigation task for this specific scenario.

The ship model had similar characteristics as military fast patrol boat (FPB) with the dimensions L 43,8 m x W 7 m x D 2,7 m. The vessel used for this experiment allowed a maximum speed of 33 knots. The main challenges for this kind of vessel is to balance efficiency and safety, which involve navigating with the highest possible speed while at the same time providing adequate levels of safety (Bjørkli, Øvergård, Røed & Hoff, 2007).

Navigational Route

An experienced navigator instructor at the Buskerud and Vestfold University College (HBV) mapped out a route of total 4,63 nautical miles in the inner Oslo Fjord (Norway) for the purpose of this study. The inner part of the Oslo fjord is characterized by particularly demanding and confined waters with numerous islets, which makes it highly challenging to navigate through this specific area. The route was divided into ten legs of varying lengths (see Figure 2 and Table. 2). The route also contained navigational information regarding turning points and courses.

Experimental Task

The navigation task was designed to engage the whole navigation team, ensuring interdependency in accordance with Salas *et al*. (1992) definition of teams. The task contained varying degrees of difficulties based on area, traffic, and weather conditions. The experimental setting was performed during daytime in good weather and visibility conditions.

Three workstations were arranged in three cubicles sectioned with blue foam boards (see Fig. 1.). The participants were not able to see each other during the experiment, however, they were required to communicate verbally in order to share information. The team members had access to the information in their own cubicles but not to the information available to the other team members. This was done to necessitate efficient and precise verbal communication to achieve successful navigational performance. The participants were divided into teams consisting of three team members. Each team member was assigned to a distinct role with belonging tasks: the *Commanding Officer (CO)*, the *Navigator*, and the *Helmsman*. The distribution of roles and tasks was designed to reflect realistic navigational teamwork common for teams navigating military fast patrol vessels (Røed, 2007; Bjørkli, 2007; Øvergård, Bjørkli, Røed & Hoff, 2010).

Fig 1. Navigator to the left, CO in the middle and Helmsman to the right in the picture.

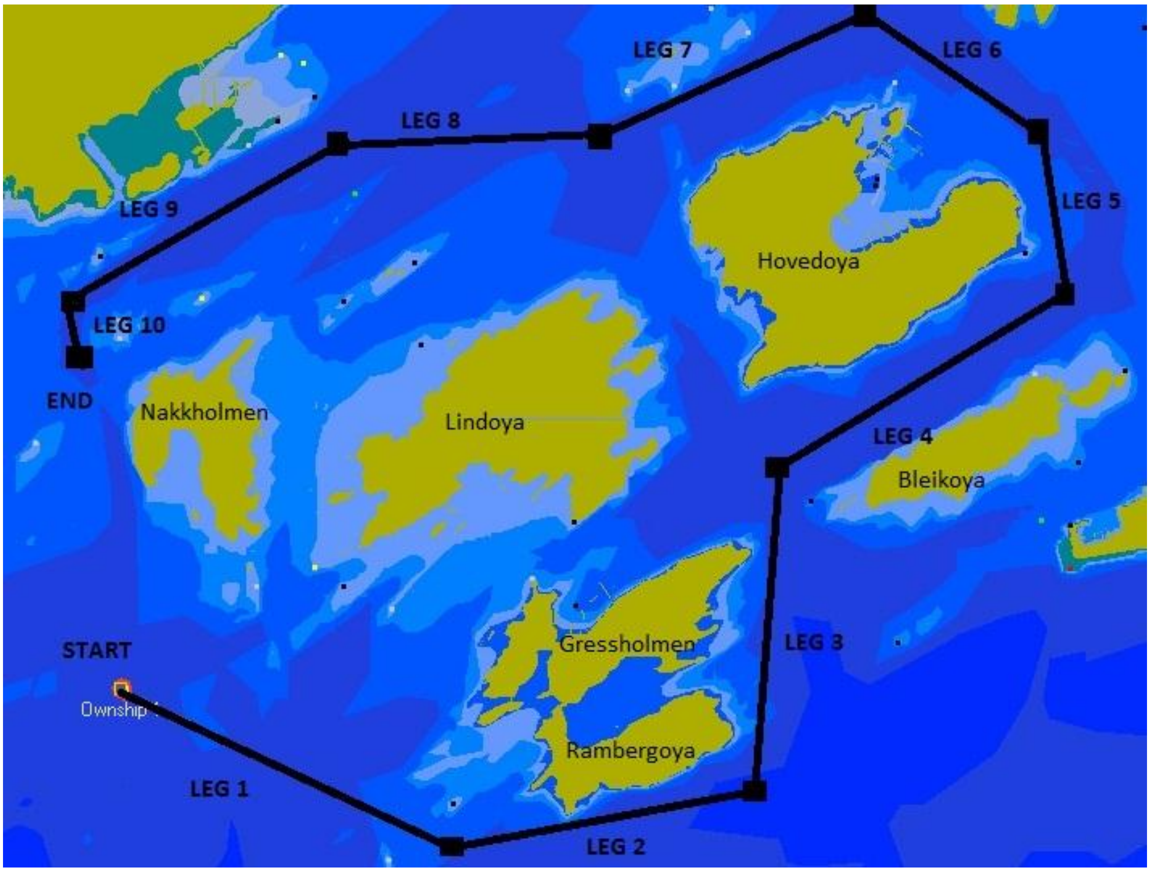

Fig. 2. Image of the navigation route and area used in the simulator experiment. The numbers indicate the legs of the route.

Table 2.

Start and end positions (in longitude and latitude) for each leg.

Leg	Latitude start	Latitude end	Longitude start	Longitude end	Distance
1	59°52.928	59°52.648	E010°41.385	E010°42.552	0.65 nm
2	59°52.648	59°52.750	E010°42.552	E010°42.598	0.54 nm
3	59°52.750	59°53.317	E010°42.598	E010°43.694	0.57 nm
4	59°53.317	59°53.629	E010°43.694	E010°44.689	0.58 nm
5	59°53.629	59°53.904	E010°44.689	E010°44.615	0.28 nm
6	59°53.904	59°54.108	E010°44.615	E010°44.010	0.38 nm
7	59°54.108	59°53.904	E010°44.010	E010°43.083	0.51 nm
8	59°53.904	59°53.890	E010°43.083	E010°42.173	0.46 nm
9	59°53.890	59°53.612	E010°42.173	E010°41.212	0.55 nm
10	59°53.612	59°53.502	E010°41.212	E010°41.224	0.11 nm

The CO. The CO's overall responsibility was to take the vessel to its destination in an efficient and safe manner. His/hers workstation was equipped with a screen displaying the visual lookout, RADAR, keyboard, and a mouse (see Fig. 3) Hence, the CO was in charge of visually monitoring and reporting the environment from the vessel's bridge to the other team members. The CO was assigned the executive role which involved making decisions regarding direction and speed based on information provided by the Navigator, the Helmsman, and information derived from his/hers own workstation.

Fig.3. The CO's workstation was provided with a visual lookout, a RADAR, keyboard, and a mouse.

The Navigator. The Navigator was responsible for handling the chart during sailing and was exclusively equipped with a nautical paper chart over the area, having no other tools available (see Fig. 4). The planned route was plotted graphically in the chart as straight lines with corresponding heading annotated in degrees from North. The navigator was responsible for monitoring the vessel`s position during sailing. Furthermore, he/she was responsible for providing the CO with information derived from the paper chart.

Fig.4. The Navigator's workstation was solely equipped with a paper chart.

The Helmsman. The workstation of the Helmsman was provided with Conning, a steering wheel, and a throttle (see Fig. 5). He/she was also equipped with Conning that presented information regarding rudder angle, water depth, heading, course, and speed. The Helmsman was in charge of steering the vessel based on commands from the CO. The commands were verbally given and the helmsman executed and verbally confirmed the commands.

Fig. 5. The Helmsman's workstation was provided with Conning, a steering wheel, and a throttle.

Briefing and Debriefing

Prior to the experiment, the participants were greeted and asked to sign a letter of informed consent, which contained information concerning ethical considerations, research objective, and guarantee of confidentiality (see Appendix B). Then they filled out a background questionnaire regarding age, gender, and nautical experience. Further, the participants were given a brief introduction of the purpose of the study and questions regarding the experiment were answered. They were also briefed on the navigation information (weather condition and traffic), constraints, the vessel's maximum speed (33 knots), and the experimental task (location). Additionally, the practical and technical matters regarding the simulator were explained to the participants. The participants were assigned to each of the workstations by the experimental leader. Before the experiment was performed, a 10-minute training trial was initiated and potential misunderstandings were resolved immediately after the trial period.

Prior to the experimental run, the team was given the nautical paper chart with the planned route they were instructed to sail, allowing them to discuss route for 5 minutes. The participants were instructed to strive to sail the pre-planned route while at the same time ensuring safe navigation. Once the participants had completed the experimental task, they were given a short instructional debriefing and a brief evaluation of their performance. Comments and questions were also handled. Finally, the participants were thanked for their effort and given two lottery tickets each.

Measurement Procedure. Two video cameras and one microphone were installed in the research lab providing audio-visual information of the teams during the experiment. The video streams and the audio stream was automatically synchronized using NOLDUS® software. This allowed for multiple perspectives on team member's work processes and communication during the experiment. In addition, navigational information regarding the vessel's position (latitude and latitude) as well as technical information about the vessel's status (ship control, heading, engine power, rate of turn, rudder angle and speed) was logged at a 2-second interval (30 observations per minute) for each trial.

Measurement of Navigational Performance. The participants were instructed to sail a planned route plotted in a chart. Team performance was measured calculating distance between the planned route and the actual sailed route, and in later analysis defined as negatively correlated to that distance. This is in line with previous research (Gould *et al.*, 2009). In other words, longer distance equals lower team performance. The logging of information of the vessel's position provided coordinates for each leg every 2 seconds. Based on this information, the distance was measured as *cross-track error* (XTE) (Han, Zhang, Noh & Chin, 2004), which is the deviation between the intended track and the actual track, was calculated. XTE is used as the way of measuring distance. In order to calculate XTE, the longitude and latitude coordinates were converted into Universal Transverse Mercator (UMT) coordinates. In short, the UMT system divides the globe into a manageable grid system and thus provides constant relationship distances in a chart. The UMT coordinate system allows for accurate identification of geographical locations (Riesterer, 2008).

Calculation of XTE was performed in Microsoft Excel using the formula below:

$$d = \frac{|(x_2 - x_1)(y_1 - y_0) - (x_1 - x_0)(y_2 - y_1)|}{\sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}}$$

where

d=distance from point to the line (equals XTE)

(x_0,y_0)=point coordinates (equals vessel position)

(x_1,y_1),(x_2,y_2)=points defining the line (equals 1st and 2nd waypoint coordinates on relevant leg)

The formula is used to calculate the shortest distance between a point and a line in a two dimensional coordinate system using analytical (Cartesian) geometry (WolframMathWorld, n.d.).The application of the formula above is straight forward for each leg handled separately. However, in order to calculate a continuous XTE during change of legs, the following method was applied:

1) For every registered vessel coordinate, the distance to all 10 legs were calculated.

2) The leg with the lowest XTE out of the 10 legs was chosen automatically as a candidate leg.

3) The route was manually reviewed and compared to the generated chart, and candidate legs that were incorrect, were corrected for. This was necessary when extension of legs were crossing the relevant leg (*e.g*. an extension of leg 4 crossed leg 1 and the vessel inevitably came closer to the extension of leg 4).

4) At the waypoints, the calculation of XTE during change of leg was done following the principle of dividing the area between the two legs using a crossline, dividing the zones between the legs in two equal parts. In the manual review of the location points, the following two different methods were used to implement this method: a) When the teams took an inner turn (see Fig. 6), the XTE was calculated using the candidate leg with the lowest XTE. b) When the teams took an outer turn (see Fig. 7), the XTE was calculated by keeping the first leg as candidate until crossing the crossline, then changed to the next candidate leg at the point of the crossline.

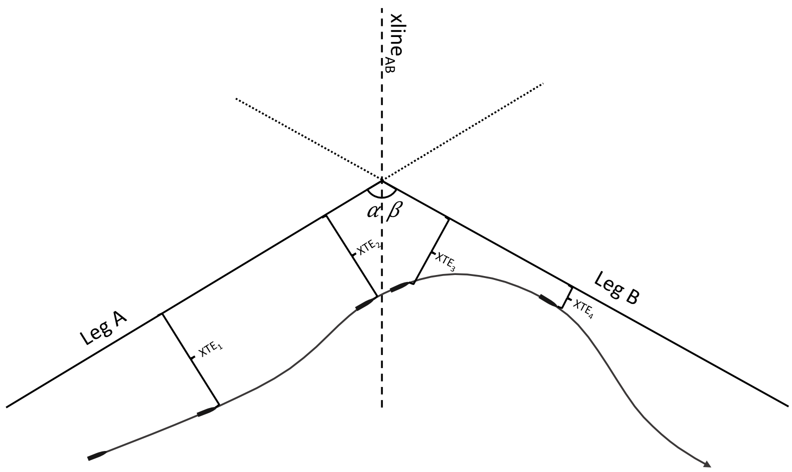

Fig 6. Illustration of method applied for calculating XTE during inner turn.

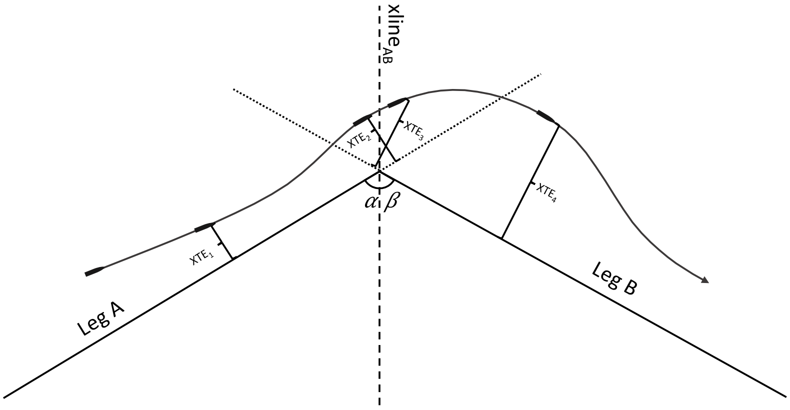

Fig 7. Illustration of method applied for calculating XTE during outer turn.

Identification of Relevant Communication

This study applied Sorensen & Stanton's (2013) method to identifying relevance of communication (relevancy is given as a ratio of relevant to irrelevant communication). The Propositional Network method was applied to define relevant information concepts for the navigational task. Stanton *et al*. (2006) claim that a Propositional Network Analysis can be performed using the Critical Decision Method (CDM) in combination with a Hierarchical Task Analysis (HTA).

Hierarchical Task Analysis. The navigational scenario was described through a Hierarchical Task Analysis (HTA). The method involved defining the navigational scenario in detail by decomposing the task into hierarchical goals, sub-goals, and operations (Anett, 2005). For this specific scenario it involved decomposition of each individual team member's tasks (see Fig. 8, 9, 10). The HTA was constructed based upon an interview with a Subject Matter Expert (SME) in navigation and existing HTA developed for military fast patrol operations (Røed, 2007; Bjørkli *et al*., 2007).

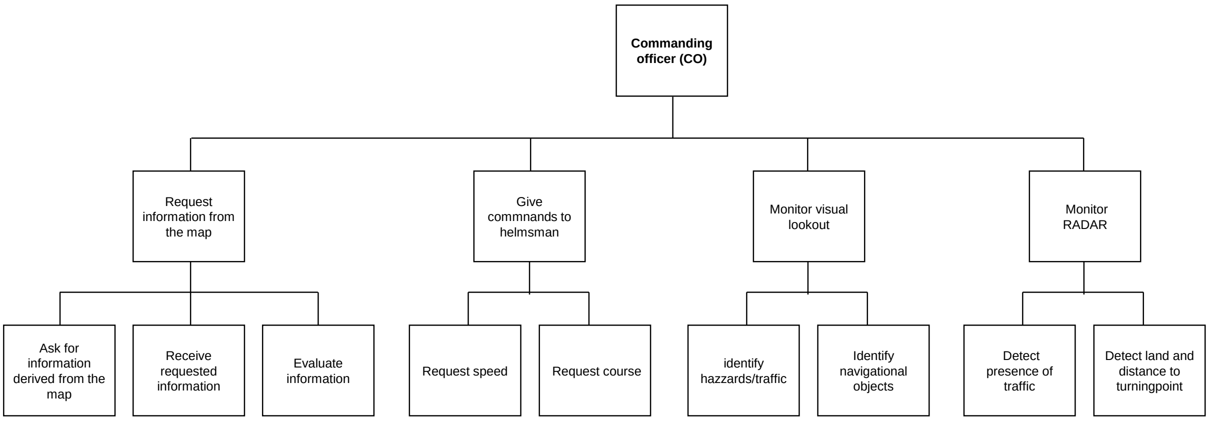

Fig 8. HTA developed for the CO's tasks.

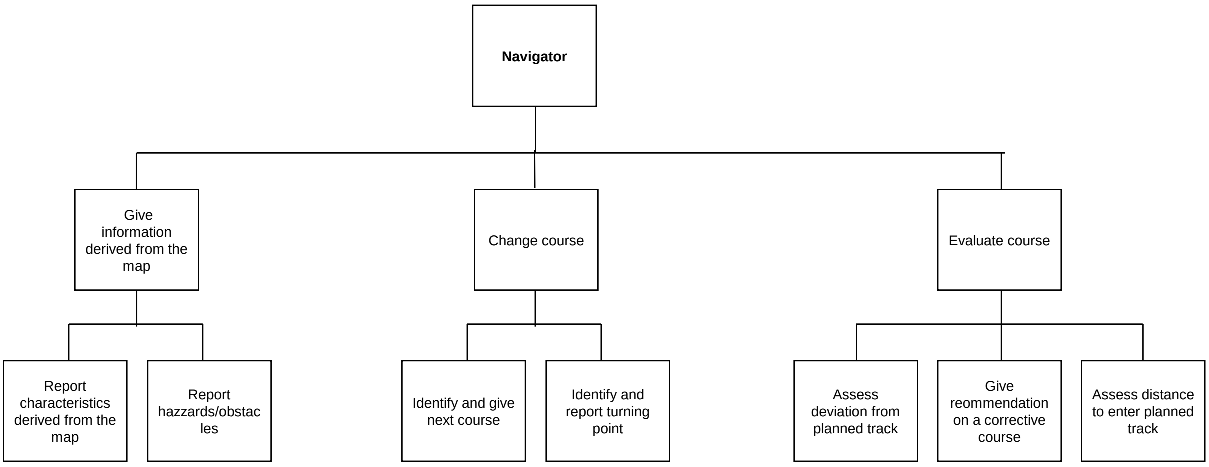

Fig 9. HTA developed for the Navigator's tasks.

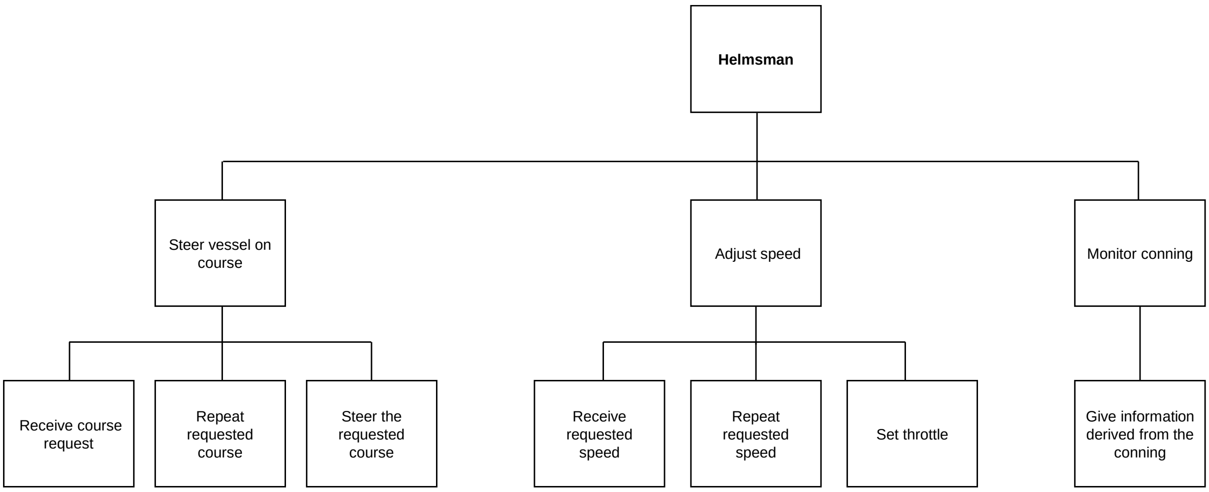

Fig 10. HTA developed for the Helmsman's task.

Critical Decision Method. A Critical Decision Method (CDM) (Klein & Armstrong, 2005) analysis of the navigational scenario was conducted. This involved a semi-structural interview (Stanton, Salmon, Walker, Baber & Jenkins, 2005) of an experienced navigator, with subject-matter knowledge in manoeuvring high speed vessel. Prior to the analysis, an appropriate set of CDM probes was developed tailored to the scenario under analysis. A content analysis transformed the CDM analysis into propositions. This involved separating content words from function words (Stanton *et al*., 2005). The CDM analysis was applied to identify factors that influence the performance of the navigational task, and the method was therefore deemed suitable for investigating characteristics of this specific navigational scenario.

Propositional Network. Based on the knowledge objects identified in the content analysis, Propositional Network diagrams were constructed. This was done by linking the knowledge objects in accordance to their association during the navigational scenario. The output of this process represents an "ideal" group of knowledge objects (Stanton *et al*., 2005) relevant for the navigational scenario. Accordingly, the Propositional Network depicts information that have been activated by agents in the system (both human and non-human) and the relationship between the various elements of information (Stanton *et al*., 2006). The method also gives indications of what knowledge the agents require in order for them to successfully perform the navigational task (Salmon *et al*., 2009). Consequently, the Propositional Network provides a comprehensive description of information elements that are relevant to communication and performance in navigation for this scenario (Salmon *et al*., 2009). The Propositional Network developed for the overarching navigational scenario (see Fig 11), was based on groupings of knowledge objects that were considered as similar, hence forming overarching categories (See Appendix C). The underlying knowledge objects were included in the Propositional Network based on frequency counts of words extracted from the CDM transcripts (Sorensen, 2012). Words that were mentioned 4 or more times were included in the Propositional Network (following Sorensen's (2012) criteria for cut-off points).

Transcription

The audio recordings were transcribed, which involved transforming the audiotaped material (communication occurring between the participants during the navigational scenario) recorded during the experiments into text. Each communication act was linked to the time-segment in which the communication act occurred, proving time-sensitive measurements. The transcripts were conducted near verbatim, however, the phrasing was slightly rewritten when it was considered to be necessary (*e.g.* pauses, yawns, groans, and sighs was excluded). Hence, the content of what was expressed was emphasized rather than the exact wording.

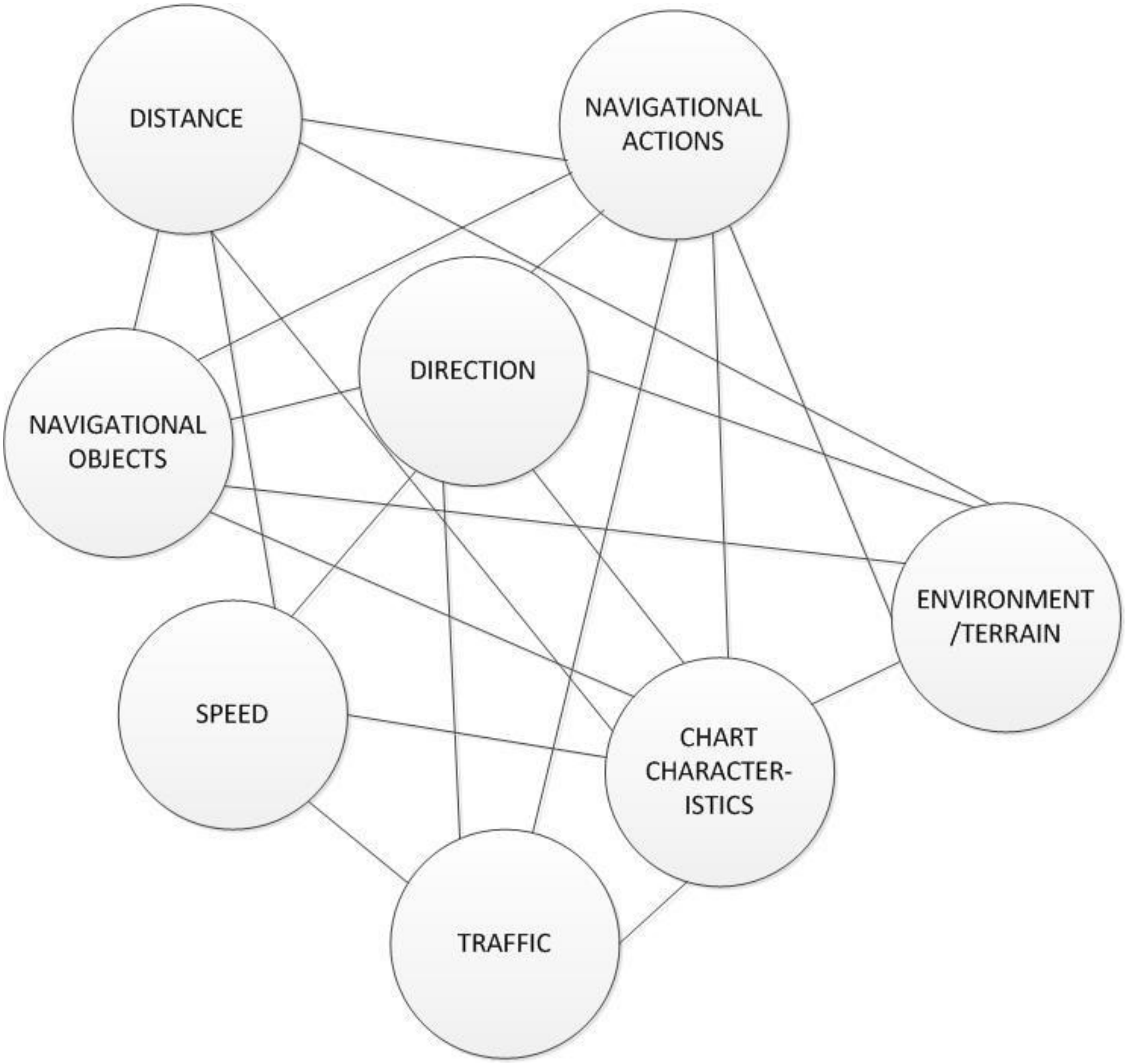

Fig 11. Propositional Network developed for the overarching navigational scenario.

Evaluating the Relevancy of Communication

Following Sorensen & Stanton's (2013) method, the identification of relevant communication was based the Propositional Network developed for this specific scenario. All statements communicated by the participants during the experiment were assessed and rated with regards to their relevancy (relevant/irrelevant) as identified in the Propositional Network.

Evaluating Correctness of Communication

The evaluation of situational correctness of communication was carried out by crosschecking the audio/video with the chart and the current position of the vessel. This was done to investigate whether the navigational team's relevant statements also included statements that were in accordance with the situation, with their visual lookout, or their plans for the near future.

Combined Communication Score of Relevance and Situational Correctness

'Good' statements. Speech acts that were coded as both relevant and correct were categorized as '*good*' and given a rating of 1 (see Table 3.) Example given below:

Navigator: "*When the vessel is 90 degrees across the pole on starboard, we must turn to course 258*".

Description: The communicated information is both relevant according to the Propositional Network and situational correct considering the specific navigational situation when this statement occurred.

'Wrong' statements. Opposite, statements deemed to be relevant and incorrect were categorized as '*wrong*' and given a score of -1(see Table 3.). Example given below:

CO: "*I can see a pole port of the vessel*".

Description: The information that is communicated is relevant according to the Propositional Network. However, in this specific situation the pole was situated starboard of the vessel. Consequently, the communication act was categorized as '*wrong*' and given a score of -1.

'Irrelevant' statements. Statements that were not specified in the Propositional Network were categorized as '*irrelevant'*. Moreover, irrelevant communication was considered as non-fitting speech acts that had no relevance for the task in progress. All irrelevant statements were coded as 0 irrespective of whether they were actually correct or not (see Table 3). Example given below:

Table 3.

The combination of relevant and correct communication was coded as 'good', whereas and relevant and incorrect communication was coded as 'wrong'. Communication that was considered as having no relevance for the task was coded as 'irrelevant'.

Communication scoring		**Relevance**	
		Yes	No
Correctness	Yes	Good 1	Irrelevant 0
	No	Wrong -1	Irrelevant 0

CO: “*Is there any coffee left?*”

Description: The communication act has no relevance for the navigational task as it is not specified in the Propositional Network developed for this specific scenario.

Instances with Absence of Communication

Instances of silence (no communication) lasting for 10 seconds or more were given a score of 0 for each 10-second interval. This was in recognition of the experimental task that were high-paced and dynamic as caused by the short navigational segments, the abundance of shallow waters, rocks and traffic, thus requiring a high frequency of communication between the team members in order to perform successfully.

Preparation of Data for Analysis

The communication scores and the XTE were averaged over each leg by calculating the arithmetic average for the two variables. Furthermore, the numbers of relevant, irrelevant, correct, and incorrect statements were counted for each of the 10 legs. The outcome of the frequency count was used to calculate the ratio of relevant statements (‘good’ + ’wrong’ statements/(‘good’ + ‘irrelevant’ + ‘wrong’ statements)), the ratio of irrelevant statements (‘irrelevant’/(‘good’ + ‘irrelevant’ + ‘wrong’ statements)), the ratio of ‘good’ statements (‘good’/(‘good’ + ‘irrelevant’ + ‘wrong’ statements)), and the ratio of ‘wrong’ statements (‘wrong’/(‘good’ + ‘irrelevant’ + ‘wrong’ statements).

In order to test *Hypothesis T1*, a running average of the communication score for the last 10 seconds was calculated for every measurement point (interval=2 sec). Lack of communication was ignored unless there was no communication during the 10 second time frame. In that case, the average was set to 0. Irrelevant communication was set to 0 and included in the running average along with communication which scored 1 or -1.

Results

The statistical analysis was performed using IBM SPSS 22 ®. Pearson correlation was calculated to estimate the association between communication and navigational team performance. The effect sizes were evaluated based on Cohen (1988, 1992) standards for small (r =.10), medium (r =.30) and large (r =.50) effect sizes.

Inter-Rater Reliability

A test of inter-rater reliability was performed to establish the reliability of the coding of the communication that occurred during the experimental scenario. An independent evaluation was done between two coders on one dataset. The statements were evaluated and rated with regards to whether they were relevant/irrelevant and correct/incorrect. The agreement between the coders were calculated and compared. The overall agreement between the coders scored a Cohen's Kappa of = 702, 95% CI [.603, .790]. An agreement of 89.6% was achieved between the coders rating of the statements. Hence, the result of the inter-rater reliability was considered as satisfactory.

Association between Communication and Team Performance

Hypothesis A1 proposed that there would be a positive correlation between the ratio of relevant communication acts and performance. Contrary to the expectations of *Hypothesis A1*, the results showed no relationship (*r* (87)= .010, 95% CI [-.166, .181]) between the ratio of relevant statements (irrespective of its correctness) and XTE. The result indicates that for context dependent activities, such as navigation, relevant communication in itself do not seem to have any association with the teams' navigational performance. Accordingly, *Hypothesis A1* was not supported by the data.

Hypothesis A2a proposed that there would be a positive association between the ratio of *'good'* statements to all statements and team performance. The results show that there was a not significant small to medium (Cohen, 1988, 1992) negative correlation (*r* (87)= -.191, 95% CI [-.381, 013]) between the ratio of *'good'* statements and XTE. Thus, *Hypothesis A2a* was not supported by the data.

Hypothesis A2b stated that there would be a negative correlation between ratio of *'wrong'* statements to all statements and team performance. In accordance with the hypothesis, a significant medium to small (Cohen, 1988, 1992) positive correlation (*r* (87)= .237, 95% CI [.060, .410]) was observed between 'wrong' statements and XTE. The result implies that teams communicating inaccurate or erroneous information tend to have decreased team performance, thus higher deviation from the pre-planned track (XTE). Consequently, *Hypothesis A2b* was supported by the data.

Hypothesis A3 proposed that there would be a positive correlation between the combined communication score and team performance. In line with the hypothesis, a significant medium to large (Cohen, 1988, 1992) negative correlation (*r* (89)= -349, 95% CI [-.521, -.226]) was observed between the combined communication score and XTE. In other words, teams that had higher number of instances of relevant and correct statements inclined to have better team performance (lower deviation from the planned track). Hence, *Hypothesis A3* was supported by the data. Fig. 12 shows mean XTE vs. mean communication rating for all measured legs across teams.

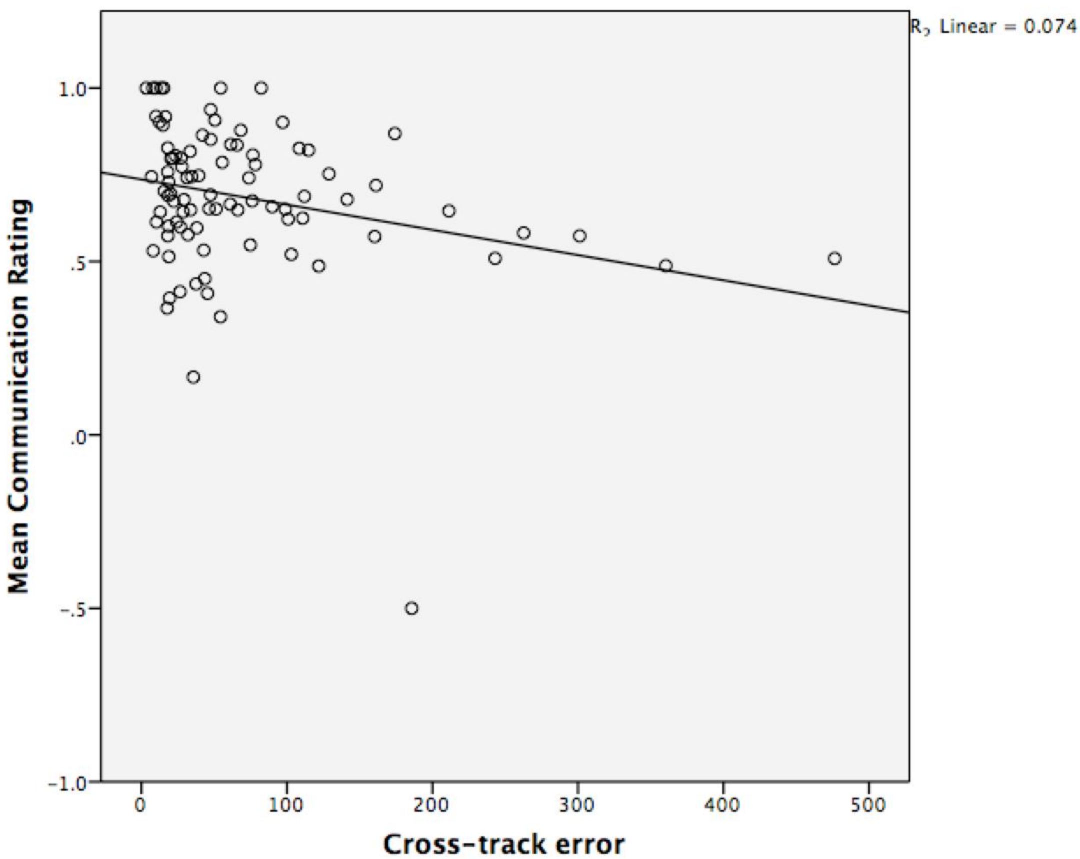

Fig.12. Scatterplot of mean communication rating (over time and legs) for each teams performance on all the legs.

Cross-Correlations

Hypothesis T1 predicted that there would be time-lagged positive correlation between communication and team performance. As hypothesized, three of the teams demonstrated time-lagged significant negative correlations between communication and XTE (outlined in bold in Table 4.). The significant correlations remain around a lag of -1, 0 and 1, indicating that the effect of communication would have to have a nearly immediate impact on team performance in order to show predictive causality. The remaining six teams displayed small correlations, which was not possible to identify statistically (see table 4). Hence, this study was not able to consistently identify the time-dependent relationship between communication and team performance. Given the few significant positive correlations between the coding of communication and team performance, *Hypothesis T1* was not fully supported by the data.

Table 4.

Time-lagged cross-correlation analysis between communication and XTE for each team. Numbers indicated in bold show the significant lagged correlations with the highest correlation. The grey areas indicate the time-lagged cross-correlations that were significant.

Lag	Team 1	Team 2	Team 3	Team 4	Team 5	Team 6	Team 7	Team 8	Team 9
-10	-.169	.027	.021	-.015	-.038	.039	-.089	-.033	-.020
-9	-.209	.037	.031	-.017	-.081	-.020	-.012	-.012	-.054
-8	-.171	.070	.003	-.034	-.046	-.009	-.042	-.023	-.024
-7	-.072	.046	.003	.013	-.024	.027	-.050	-.023	-.037
-6	-.059	.036	-.015	-.003	-.039	.067	-.052	-.028	-.033
-5	-.092	.033	-.002	.035	-.013	.027	-.016	-.050	-.031
-4	-.080	.043	.044	-.015	.009	.048	-.072	-.056	-.079
-3	-.107	.043	.058	-.018	-.009	.013	-.041	-.122	-.059
-2	-.160	.015	.039	.006	.023	.028	-.047	-.113	-.051
-1	-.136	.024	.061	-.021	.009	.008	-.033	**-.143**	-.068
0	**-.249**	.048	.040	-.022	-.035	.071	-.077	-.122	**-.138**
1	-.114	.036	.024	-.043	.011	-.005	-.040	-.094	-.091
2	-.170	.071	.067	-.033	.001	.011	-.059	-.062	-.066
3	-.179	.028	.052	.005	.034	.002	-.042	-.061	-.068
4	-.123	.052	.029	.000	.024	.007	-.036	-.049	-.078
5	-.127	.039	-.016	.016	.011	.022	.007	-.055	-.082
6	-.168	.076	-.035	-.005	-.033	.045	-.023	-.006	-.092
7	-.166	.024	-.008	.008	-.015	.015	.036	-.031	-.090
8	-.184	.043	-.003	.018	-.001	.039	-.066	-.039	-.038
9	-.160	-.020	.002	.015	.013	.029	-.036	-.039	-.056
10	-.047	.024	.034	.015	.000	.060	-.058	-.052	-.090

Discussion

The main purpose of the present study was to investigate whether relevance *and* correctness of communication during high-speed coastal navigation is associated with navigational team performance. In order to do this, the design of the study incorporated three discrete aims. The first aim was to examine the relationship between relevant communication and team performance based on the method developed by Sorensen & Stanton (2013). Second, the study aimed to extend the method developed by Sorensen & Stanton (2013) by including assessments of situational correctness of information and investigating how both relevance and correctness of the navigational teams' statements are associated with navigational team performance. Ultimately, the study made an attempt to identify the time-dependent relationship between the communication measures (reflecting DSA) and team performance.

Considering the results of the present study, relevant communication did not show any relationship to team performance (r = .01). The ratio of '*Good*' communication demonstrated a not significant small to medium correlation with XTE (r = -.191), while the ratio of '*Wrong*' communication yielded a significant medium to small correlation with XTE (r = .237). Moreover, the combined communication score had a moderately large negative correlation with XTE, the correlation (r = -.349). The present study was able to identify a significant time-dependent association between communication and team performance for three of the nine teams in the experiment.

In total, these extensive investigations were intended to advance our understanding of the relationship between DSA and team performance. As such, the present research adds to the line of inquiry trying to explore the relationship between the mentioned variables. The subsequent discussion aim to illuminate the different explanations of the results of this study.

The lack of support for the hypothesized association between the ratio of relevant statements (irrespective of its correctness) and team performance (r = .01) revealed in the present study was somewhat surprising, as the results did not correspond with the large effect size (r = .923) observed by Sorensen & Stanton (2013). The diverging findings between the present study and Sorensen & Stanton's (2013) study might be due to the variation of tasks in the two experimental settings. Sorensen & Stanton (2013) performed a controlled experimental study based on a command and control task simulated in a strategy game. The present study performed as a natural experiment conducted in a navigational simulator.

Additionally, the task in the present was highly dynamic as the activity changed continuously based on the team members' navigational activity and on changes in the navigational environment (*e.g.* other vessel's movement). Hence, the divergent results can have occurred due to the highly contextualized activity of coastal high-speed navigation (see *e.g.* Øvergård *et al*., 2010; Bjørkli *et al*., 2007) that require the team must adapt quickly to situational changes (Salmon *et al*., 2009; Bjørkli *et al*., 2007). Summarized, a task with higher probability of agents communicating incorrect information will require evaluation of both correctness and relevance in order to establish an association with team performance.

Furthermore, the results for *Hypothesis A1* that showed that there was no relationship between relevant communication and team performance can be understood in light of Flach's (1995) argumentation of correspondence. According to Flach (1995) sociotechnical systems require consideration of the connection between the processed information and the conditions in the environment. Hence, exclusively assessing communicated information with regards to its relevance is not sufficient. Both relevance and veridicity of the communicated information need to be evaluated.

Similarly, Salmon *et al*. (2009) have addressed the issue with quality of shared information, stating that the quality of the SA transactions taking place in a team setting need also be evaluated. Likewise, Stanton *el al*. (2006) have also engaged the matter regarding correctness, arguing that a situation requires the use of appropriate knowledge that relates to the state of the system and the changes that occur as a consequence of variations in the situation. Evidently, issues concerning appropriateness and correctness of information are important concerns discussed by several researchers. However, despite the presumed importance of this issue, there seems to be few studies evaluating how the correctness of communication may impact team performance.

In order to take into account the issue related to the correctness of information, the present study included assessments of correctness of information shared between the team members. The effect of including evaluations of situational correctness was tested for in *Hypothesis A2b* and *Hypothesis A2b*. Both '*good*' and '*wrong*' statements had a small to medium correlation with team performance (only significant for '*wrong*' statements). Despite the low correlations, the correlations were in the direction initially anticipated. Additionally, evaluation of the effect size and the confidence interval of the relationship between '*good*' statements and team performance give reason to believe that a larger sample size would reveal a significant association.

More interestingly, the result of *Hypothesis A3* which revealed that the communication score had a significant association with XTE (r = -.349), further strengthen and confirms the proposal of evaluation of correctness of communication. The result of *Hypothesis A3* should be considered in relation with the results of *Hypothesis A1*, which showed that relevant statements did not a have a significant association with team performance. When the combination of both relevancy and situational correctness of the communication was evaluated, a significant relationship between communication and team performance was evident. Overall, the results of hypotheses A1-3 in sum, indicate that evaluation of relevancy and correctness of communication are a better measure of the content of SA compared separately evaluating relevant communication. Based on the result it can be argued that relevant communication in separation may to a greater extent be an indicator of domain knowledge rather than a state that reflects DSA. Correctness on the other hand, is dependent on the operator ability to situational adaption. Information can be relevant without being correct. Relevancy and correctness are characteristic that SA should contain. The content of SA should be correct and relevant - irrespective of the cognitive processes underlying SA (Flach,1995).

The results of this study indicate that the relevance of communication is not sufficient to ensure good teamwork. This is simply because a relevant statement can be incorrect (*e.g.* lacking veridicity) and therefore be harmful to task performance. Similarly, the veridicity of statements (*e.g* situational correctness) is also not sufficient for successful team performance, as irrelevant statements can be factually correct ("*there is no more coffee*"). Accordingly, the content of DSA must contain the two characteristics of task relevance and situational correctness. Only when both relevancy and correctness of communication is present, the content of SA can be assessed. Based on the findings of the following formula can be developed for content of SA:

Content of SA= *Relevant information + correctness of information*

Time-Dependent Measures

Hypothesis T1 was only partially supported by the data as three out of nine teams showed significant lagged correlation between communication and team performance. As anticipated, some of the lagged correlations were positive, however, the majority of cross-correlations were not significant. Additionally, most of the lagged correlations were not consistent, showing moderate to no time-lagged relationship between communication and team performance. Due to the divergent results of the cross-correlation, it is necessary to discuss the potential reasons for these results.

The inconsistent results of the cross-correlation might stem from the teams' various control strategies. The teams may have developed different strategies for coping with the challenges approached in the navigational scenario (*e.g.* Øvergård *et al*., 2010). For example, in order to navigate safe and efficiently, the teams can deliberately have chosen a track that involved deviation from the planned track in order to get a position that could improve their navigational ability in future tracks (Bjørkli *et al*., 2007). The present study did not investigate the possible implications of control strategies. Future research might bring to test this possibility.

Time-pressure is another matter that may have influenced the results of the cross-correlation between communication and team performance. The time each team use to process information may vary across the teams. Hence, teams that use longer time to process information regarding the navigational situation, would most likely have problems related to time pressure. Hollnagel (2002) argue that control and time are essential elements in human action. Breakdown of control may easily occur when time is scarce (Hollnager, 2002). Time pressure can develop when there is a mismatch between the internal capacity (information processing abilities) and the external demands. Hence, time pressure is dependent on at which speed the team can solve the tasks (Hollnagel, 2009). This might have been the case for several teams in this experiment, which can help to explain the divergent results across the teams.

Although the result of *Hypothesis T1* was partially supported by the data, this investigation has important implications for future research. The exploration of the time-dependent relationships between communication and team performance can be an important contribution to the SA literature. A limited number of previous research have investigated the dynamic association between SA and team performance. As such, this study represents one of the first investigations of the time-dependent of this relationship, trying to identify Granger causality between communication and team performance. While the current investigation only provide significant results for three of the teams, these early yet promising results give reason for future attempts to examine the time-dependent relationship between communication and team performance.

The varying results of Hypothesis T1 might also stem from the quality of communication coding. The communication coding system applied in this study might be sufficient to describe relevance and correctness on an aggregated level. However, when it comes to describing same attributes on a more granular level (*i.e.* time frames of seconds) a more complex coding system could prove valuable.

Implications for the SA Construct

The results of the present study may have implication for the concept of SA. The majority of the existing SA models focus on the cognitive processes involved in developing and maintain SA (see *e.g.* Endsley, 1995a; Smith & Hancock, 1995; Bedny & Meister, 1999). For instance, Endsley’s (1995a) three level model of SA offer a framework for investigating the elements of the process involved in achieving SA. Whilst important for understanding the individual operators awareness, Ensley`s model of SA do not provide knowledge of what the cognitive processes should contain. The present study has demonstrated that SA is not solely a question of the process of SA but also the content of SA and therefore what agents of a system should be cognizant about (Flach, 1995). The content of SA that embodies the two characteristics of relevancy and correctness is necessary for operators in order to appropriately update their mental processes involved in developing SA. Hence, developing SA is not just about support of the cognitive processes involved in developing SA but also about ensuring that the content of these processes are relevant and correct.

Another implication of the result of the present study is the distinction between domain task competence and situational adaption. Based on this study it can be argued that relevant communication in separation may be an indicator of domain- or task competence rather than a state that reflects DSA. Relevant communication is abstract and general is therefore applicable across tasks with similar control requirements (see Table 5).

Domain knowledge directs what is to be considered as meaningful in a situation, hence it also directs where the agents' focus their attention (see *e.g.* Goodwin, 1994). However, it does not necessarily mean that agents perceive what he/she need to know in order to act appropriately in relation to the situation (see *e.g.* Simons & Chabris, 1999). Integrating information that seemingly are considered as relevant, but which is in fact incorrect, can lead to agents updating their SA based inadequate or erroneous information. This again can disrupt the systems awareness which can have unfortunate consequences (Stanton *et al*., 2006).

Correctness on the other hand is concerned with the agent's adaption towards the situation, hence correctness is specific for the individual situations occurring there and then (see table. 5) In short, domain task competence is the ability evaluate what is relevant in situation, whereas correctness enables the ability to adapt to the situation through picking up information that is specific to each situation.

Table 5.

The table indicate the difference between relevancy and correctness

SA Contents	**Area**	**Generality**
Relevancy	Domain Task Competence	Abstract/General
Correctness	Situational Adaptation	Specific/Situational Dependent

Limitations of the Present Study

The findings presented in this paper need to be considered in light of limitations associated with the design and methodology of the investigation.

Sample Size. In the current study, the complete dataset consisted of 9 teams with three participants in each team. Following Cohen´s (1988, 1992) calculations for effect sized the sample should ideally have consisted of minimum 12 teams. The number of teams participating in the study was what was possible to attain within this specific sample pool. However, each team's performance was measured on the 10 legs in the planned route and their scores were compared for each of the legs. The repeated measures resulted in total 90 observations (9 team x 10 legs), hence providing a sufficient amount of observations.

Participants. The participants in the present study were nautical students and as such not as experienced as professional navigators. However, it expected that association between relevance and correctness of statements and team performance would still be present in groups of experienced navigators. Furthermore, the participants were self-selected which is often associated with self-selection biases (*i.e.* the decision to participate in the study may reflect some bias in the characteristics of the participants) (Heckman, 1990). Additionally, there was done no randomisation of the team members with regards to age or experience, which might have led to some team being more experienced than others. This might have caused selection biases, which is a possible consequence of lack of randomisation. Therefore, future research should strive to evenly distribute the team members in order to ensure equivalent groups.

Coding. The findings of this study indicate that the method can be improved by refining the weighting of 'good', 'wrong' and 'irrelevant' statements, which can potentially increase the reliability of the presented method. More sophisticated and refined coding system with emphasis on communication patterns and content can potentially generate deeper information regarding the communication acts.

Validity. The experiment was conducted in desktop simulator which provided realistic and detailed re-creations navigational conditions. However, the simulator does not necessary provide an accurate picture of navigation. Real danger and the real consequences of actions might not occur in the simulator, which can give the participants a false sense of safety, responsibility, or ability (Käppler, 1993; Øvergård, Bjørkli, Hoff & Dahlman, 2005).

Furthermore, the participants may also experience the simulator as having low-fidelity which can potentially have evoked unrealistic navigation behaviour or demotivation (Lee, 2004) towards the navigational task. Both the mentioned issues can cause lack of facevalidity and ecological validity. Consequently, future research should strive to test the navigational scenario in natural settings or conduct field studies whereby navigators can be observed during real-time performance. Hence, providing data that can be compared to data generated during the simulator experiment.

Conclusion

The results of this study showed no relationship between relevant communication and team performance. When the combination of relevancy and correctness of communication was accounted for, an association with team performance was observed. The results indicate that exclusively assessing communicated information with regards to its relevance is not sufficient for establishing an association with team performance in context-specific tasks such as coastal high-speed navigation.

Furthermore, this study was able to identify a statistical time-dependent relationship between communication and team performance for three of the nine teams in the experiment. Given the variation between the teams, future research is needed in order to gain more suitable support for these initial findings.

The early, yet promising findings in this study may serve as a foundation for the development of a simple but comprehensive method for observation that allows for assessment of team performance in complex and context-dependent work tasks.

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Appendix A

Norsk samfunnsvitenskapelig datatjeneste AS
NORWEGIAN SOCIAL SCIENCE DATA SERVICES

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www.nsd.uib.no
Org.nr. 985 321 884

Kjell Ivar Øvergård
Psykologisk institutt Universitetet i Oslo
Postboks 1094 Blindern
0317 OSLO

Vår dato: 20.01.2015	Vår ref: 41545 / 3 / SSA	Deres dato:	Deres ref:

TILBAKEMELDING PÅ MELDING OM BEHANDLING AV PERSONOPPLYSNINGER

Vi viser til melding om behandling av personopplysninger, mottatt 11.01.2015. Meldingen gjelder prosjektet:

41545	*Assessing navigational teamwork through the situational relevance of communication*
Behandlingsansvarlig	*Universitetet i Oslo, ved institusjonens øverste leder*
Daglig ansvarlig	*Kjell Ivar Øvergård*
Student	*Astrid Rynning Nielsen*

Personvernombudet har vurdert prosjektet og finner at behandlingen av personopplysninger er meldepliktig i henhold til personopplysningsloven § 31. Behandlingen tilfredsstiller kravene i personopplysningsloven.

Personvernombudets vurdering forutsetter at prosjektet gjennomføres i tråd med opplysningene gitt i meldeskjemaet, korrespondanse med ombudet, ombudets kommentarer samt personopplysningsloven og helseregisterloven med forskrifter. Behandlingen av personopplysninger kan settes i gang.

Det gjøres oppmerksom på at det skal gis ny melding dersom behandlingen endres i forhold til de opplysninger som ligger til grunn for personvernombudets vurdering. Endringsmeldinger gis via et eget skjema, http://www.nsd.uib.no/personvern/meldeplikt/skjema.html. Det skal også gis melding etter tre år dersom prosjektet fortsatt pågår. Meldinger skal skje skriftlig til ombudet.

Personvernombudet har lagt ut opplysninger om prosjektet i en offentlig database, http://pvo.nsd.no/prosjekt.

Personvernombudet vil ved prosjektets avslutning, 04.05.2015, rette en henvendelse angående status for behandlingen av personopplysninger.

Vennlig hilsen

Vigdis Namtvedt Kvalheim

Sondre S. Arnesen

Kontaktperson: Sondre S. Arnesen tlf: 55 58 33 48

Dokumentet er elektronisk produsert og godkjent ved NSDs rutiner for elektronisk godkjenning.

Avdelingskontorer / District Offices:
OSLO: NSD. Universitetet i Oslo, Postboks 1055 Blindern, 0316 Oslo. Tel: +47-22 85 52 11. nsd@uio.no
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TROMSØ: NSD. SVF, Universitetet i Tromsø, 9037 Tromsø. Tel: +47-77 64 43 36. nsdmaa@sv.uit.no

Appendix B

Forespørsel om deltakelse i forskningsprosjektet

"Assessing Navigational Teamwork through the Situational Relevance of Communication"

Bakgrunn og formål

Formålet med dette studiet er å undersøke hvorvidt relevant kommunikasjon mellom teammedlemmer innen navigasjon vil påvirke deres prestasjon. Dette vil bli undersøkt ved å gjøre tidsavhengig målinger av teammedlemmenes kommunikasjon og prestasjon for å vurdere disse mot hverandre. Det vil bli gjort video- og lydopptak fra studien som senere vil bli brukt i analysearbeid.
Prosjektet er en del av et masterstudie i arbeids- og organisasjonspsykologi ved Universitetet i Oslo.

Deltakerne i studiet forespørres om å delta på frivillig bakgrunn. Utvalget av deltakerne er basert på deres kunnskap og erfaring innen navigasjon. Deltakerne blir tilfeldig fordelt på forskningsgrupper på tre og tre.

Hva innebærer deltakelse i studien?

Studien innebærer en interaktiv teamøvelse hvor teamene vil bli bedt om å løse en navigasjonsoppgave i en desktop båtsimulator (Kongsberg Polaris). For å kunne løse oppgaven må deltakerne kommunisere med hverandre. Dataen fra studien registreres ved hjelp av lyd- og filmopptak som senere vil bli brukt til å registrere og observere deltakernes kommunikasjon.

Hva skjer med informasjonen om deg?

Alle personopplysninger vil bli behandlet konfidensielt. De som vil ha tilgang til personopplysninger og øvrig datamateriale er forskningsgruppen innen teknologi og maritime fag.

Deltakerne i studien vil ikke kunne gjenkjennes i en publikasjon.

Prosjektet skal etter planen avsluttes 04.05.2015 med mulige forlengelse. Lyd- og filmopptak som har blitt samlet inn som en del av datainnsamlingen, vil bli slettet ved prosjektslutt. Alle personopplysninger vil også bli slettet.

Frivillig deltakelse

Det er frivillig å delta i studien, og du kan når som helst trekke ditt samtykke uten å oppgi noen grunn. Dersom du trekker deg, vil alle opplysninger om deg bli anonymisert.

Dersom du ønsker å delta eller har spørsmål til studien, ta kontakt med Astrid Rynning Nielsen på astridrynnie@gmail.com eller på telefon 474645393. Daglig leder for studien Kjell Ivar Øvergård kan også kontaktes på koe@hbv.no.

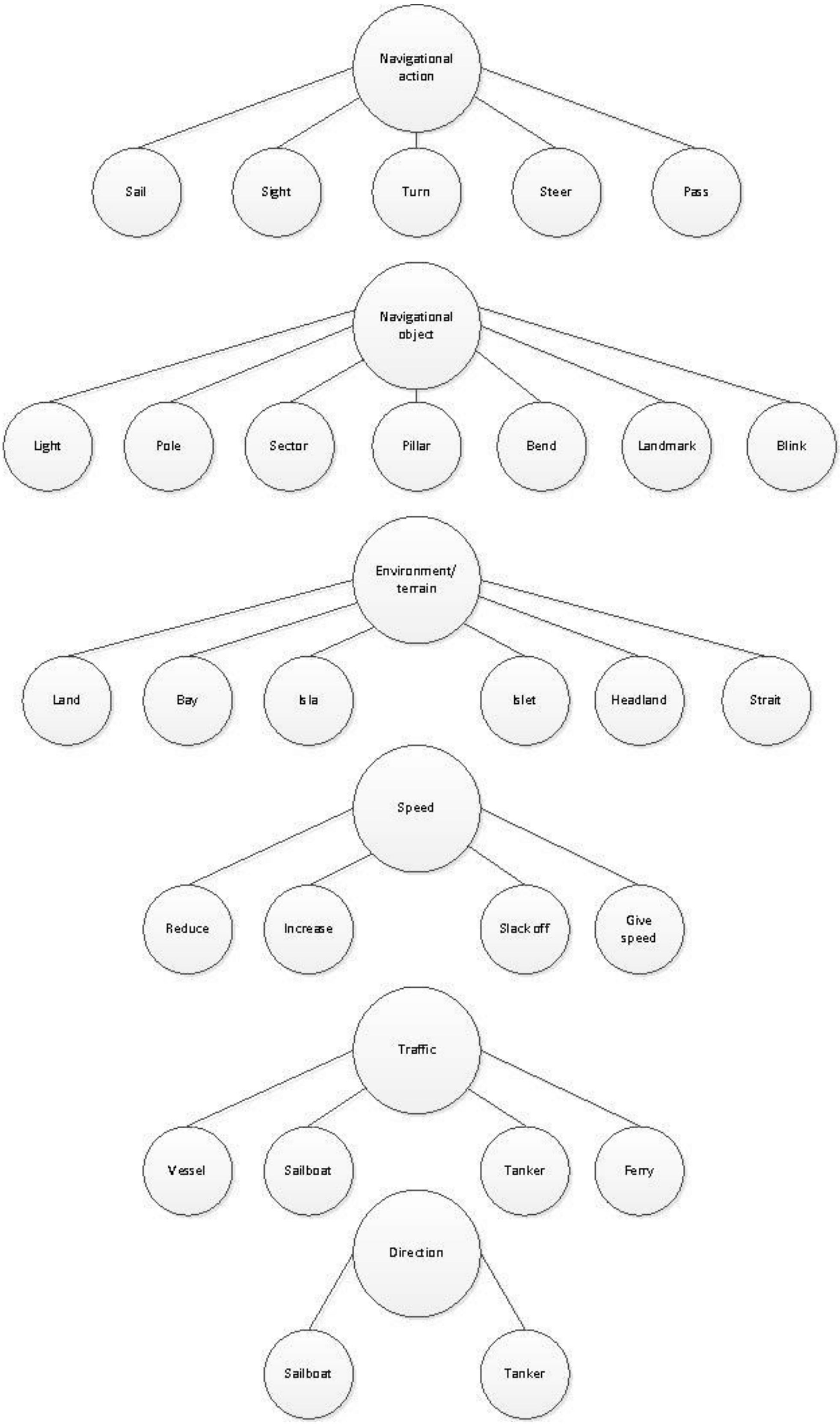
Studien er meldt til Personvernombudet for forskning, Norsk samfunnsvitenskapelig datatjeneste AS.

Samtykke til deltakelse i studien

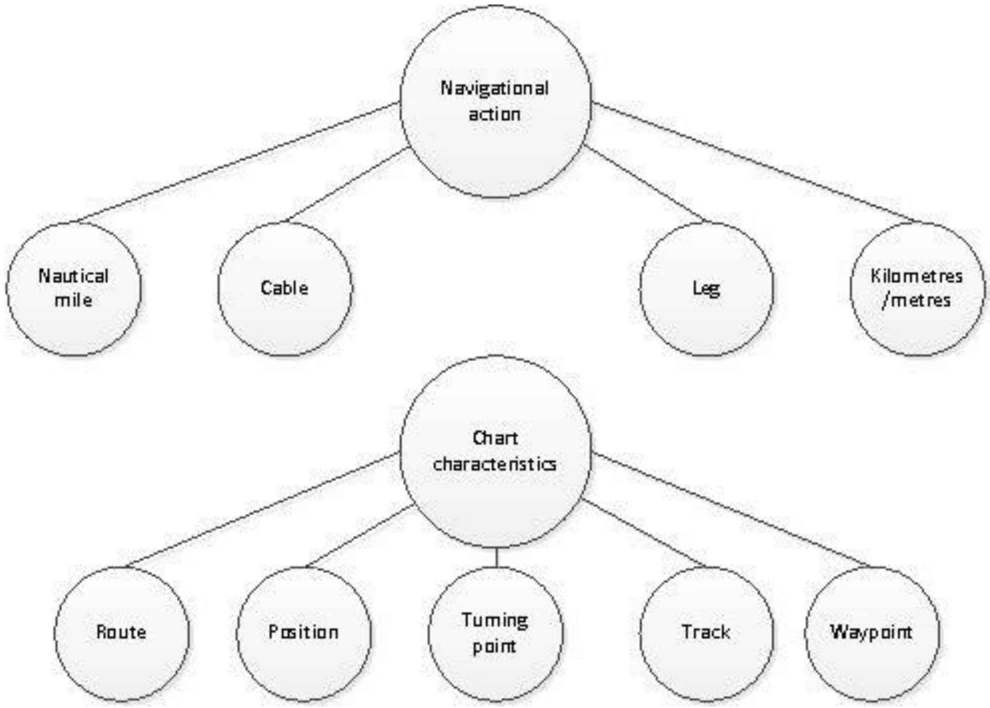
Jeg har mottatt informasjon om studien, og er villig til å delta

----
(Signert av prosjektdeltaker, dato)

Appendix C



Navigational action
Sail
Sight
Turn
Steer
Pass
Navigational object
Light
Pole
Sector
Pillar
Bend
Landmark
Blink
Environment/ terrain
Land
Bay
Isla
Islet
Headland
Strait
Speed
Reduce
Increase
Slack off
Give speed
Traffic
Vessel
Sailboat
Tanker
Ferry
Direction
Sailboat
Tanker


Navigational action
Nautical mile
Cable
Leg
Kilometres /metres
Chart characteristics
Route
Position
Turning point
Track
Waypoint